Faculty of Resource Science and Technology

FORAGING ECOLOGY OF INSECTIVOROUS BATS IN UNIVERSITI MALAYSIA SARAWAK (UNIMAS) CAMPUS

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This project is submitted in partial fulfillment of the requirements for the degree of
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DECLARATION

No portion of the work referred to in this dissertation has been submitted in support of an application for another degree of qualification of this or any other university or institution of higher learning.

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ABSTRACT

This study describes the feeding ecology of insectivorous bats under natural condition at light source in Universiti Malaysia Sarawak (Unimas) campus. Throughout 18 nights of sampling that was conducted from October 2005 to February 2006, only two species of insectivorous bats namely *Kerivoula papillosa* and *K. pellucida*, were observed foraging at the light sources. The activity of insectivorous bats foraging at the study sites were detected using Mini-3 bat detector while the insect activity was determined by the number of insects collected at each sampling site using light sheet trap. The result shows that insectivorous bat activity was positively correlated with insect activity (Pearson's correlation coefficient at 0.05 level) and insectivorous bat feeds on insects regardless of their sizes.

Key words: Insectivorous bats, insect, relationship, activity, size.

ABSTRAK

Kajian ini menjelaskan tentang tabiat pemakanan kelawar pemakan serangga di dalam keadaan semulajadi pada sumber cahaya yang terdapat di kawasan kampus Unimas. Sepanjang 18 malam persampelan yang dijalankan dari bulan Oktober 2005 hingga Februari 2006, dua spesis kelawar pemakan serangga iaitu Kerivoula papillosa dan K. pellucida telah dilihat mencari makanan di sumber cahaya tersebut. Aktiviti kelawar pemakan serangga dikesan menggunakan pengesan kelawar Mini-3 manakala aktiviti serangga ditentukan dari bilangan serangga yang dikutip dari perangkap skrin. Keputusan menunjukkan bahawa aktiviti kelawar pemakan serangga berkait secara positif dengan aktiviti serangga (Korelasi koefisien Pearson pada level 0.05) dan kelawar pemakan serangga memakan serangga tanpa mengira saiz.

Kata kunci: Kelawar pemakan serangga, serangga, perkaitan, aktiviti, saiz.

1.0 INTRODUCTION.

Chiroptera is divided into two suborders, Megachiroptera and Microchiroptera. Megachiroptera are generally larger bats and mostly are frugivorous while Microchiroptera consists of smaller bats that include the insectivorous bats and vampire bats (Richardson, 1985). About one third of bat species eat fruit and the rest are insectivorous (Richardson, 1985).

There are 16 families of insectivorous bats in the world (Findley, 1993) and seven families, Emballonuridae, Megadermatidae, Nycteridae, Rhinolophidae, Hipposideridae, Vespertillionidae, and Molossidae, are found in Borneo (Payne *et al.*, 1985).

Kunz (1982) stated that the diversification of roosting and feeding behavior, reproductive strategies and social behaviors are mainly caused by the evolution of flight and echolocation. Insectivorous bats have small eyes, therefore they use the echolocation for navigation during flight and also to obtain information about their environment including the presence, position, speed, and identification of potential prey (Richardson, 1985).

Insectivorous bats have several evolved characteristics such as the teeth and echolocation in order to adapt to their feeding behavior. The milk teeth of the baby bats will become the permanent teeth after a couple of weeks and those permanent teeth are designed for insects (Richardson, 1985). The molar teeth with 'W' shaped tips will help to cut up and crush the insect food while the long and pointed canines are useful to grip the struggling insects. When dealing with large insects, the bats will chew by the side of the mouth with the insects protruding out (Richardson, 1985). However, there are also differences between the dentition of insectivorous bats that consume hard-shelled and soft-bodied insects (Freeman, 1979).

Insectivorous mammals like bats and shrews benefit human by helping to control insect pest (Booth, 1982). Microchiroptera are carnivorous feeding mainly on insects but some species also feed on small vertebrates like mammals and reptiles and also mammal blood (Richardson, 1985). Bats are nocturnal so the day-flying butterflies and wasps and other terrestrial insects are caught infrequently (Kunz, 1982). The diet of insectivorous bats includes a wide range of insects (Tan, 1965; Churchill, 1994; Jalaweh, 2004) and the commonly consumed orders are Orthoptera, Coleoptera, Diptera, and Hymenoptera (Tan, 1965).

The study of insectivorous bats feeding habits is important as bats are thought to play an important role in influencing insect populations both in agriculture habitats and forests where it acts as biological control agent for some of the major insect pests that badly affect the agricultural sector (Zubaid *et al.*, 2004). Therefore, this study will focus on the foraging activity of insectivorous bats around Universiti Malaysia Sarawak (Unimas) area.

1.1 Problem statement

Although the Chiroptera order has tremendous diversity, they are still poorly understood (Findley, 1993). Because of their nocturnal nature and their ability to fly, bats have been the subjects of relatively few studies and our knowledge of them lags behind that of other more conspicuous mammals. For example, we do not know whether insectivorous bats maximize their foraging activity to period of high abundance of insects and whether bigger bat choose bigger prey or they just forage at random. In a study that was done by O'Neill and Taylor (1989), there was a relationship between bat forearm length and the size of prey since smaller insectivorous bat species like *Lasiurus borealis* in Canada did not eat larger prey because of the difficulties associated with capturing or handling such prey (Hickey *et al.*, 1996).

1.2 Objectives and hypothesis

1.2.1 Objectives

This study addressed the following questions:

1) Does variation in bat and insect activity follow a consistent and congruent pattern, for example do bats time their foraging activity to coincide with peak abundances of their prey? If so, the relationship between foraging activity and insect abundance will be strongly positive.
2) Does difference of peak foraging activity occur between different bat species and does this coincide with different prey size?

1.2.2 Hypothesis

1) An optimal forager will maximize it foraging activity to coincide with period of high prey abundance. Therefore, it is predicted that foraging activity of insectivorous bat will be positively correlated with insect abundance.
2) Bigger prey is more profitable than smaller one as it yield a higher amount of energy per unit of pursuit and handling time. Therefore, it was predicted that very small insect are seldom taken as they are not profitable. Prey bias towards larger insects was also predicted until a certain weight ratio is reached since the bat needs more energy to carry bigger insects.

2.0 LITERATURE REVIEW

Diet of insectivorous bats.

Insectivorous bats feed on insects of different kinds in different ways and at different heights, from non-flying insects on the ground or on water surfaces to insects flying as high as 3000 m above the ground (Sales and Pye, 1974). The food habits of insectivorous bats can be influenced by several factors, including the time of nightly emergence, seasonally changing energy and nutrient demands, temporal and spatial distribution of their prey and prevailing climatic and meteorological conditions (Whitaker *et al.*, 1996). From studies that was done by Black (1972, 1974) and Husar (1976), moths and beetles generally contribute the greatest part to the diet of temperate insectivorous bats. Additional insect orders represented in the diet of bats include Hymenoptera, Diptera, Homoptera, Hemiptera, Neuroptera, Trichoptera, Orthoptera, and Odonata (Gaisler, 1979). Diptera may strongly predominate in the diet of smaller bat species (Belwood and Fenton, 1976) and Ephemeroptera in diet of species foraging over water bodies (Gaisler, 1979). Competition for food is mostly avoided through different foraging strategies and partial specialization to different size and taxonomic group of insects.

According to Fenton (1982) there are approaches in the study of feeding behavior of insectivorous bats including by analyzing the stomach content of bats, as what Jalaweh (2004) did or by monitoring their foraging behavior using the bat detector. The diet of insectivorous bats includes a wide range of insects (Tan, 1965; Churchill, 1994; Jalaweh,

2004) and the commonly consumed orders are Orthoptera, Coleoptera, Diptera, and Hymenoptera (Tan, 1965).

Insectivorous bats have poor eyesight, yet they are able to fly at high speed in the dark, often through complex environments and many live exclusively on small insects intercepted in mid-air. The first detected ultrasonic signals of bats was in 1938 (Sales and Pye, 1974). The ultrasounds that are in 20-150 kilohertz range are produced in the larynx, and the returning echoes will guide the bats in their flight navigation and pursuit of prey (Findley, 1993).

Insectivorous bats activity.

According to Hayes (1997), the activity of bats is not significantly correlated with either the phase of moon or hours of moonlight. Its level of activity usually peaked after the sunset and a smaller peak shortly before the sunrise. However, the patterns of activity may vary between nights in response to external and internal factors such as abundance of insects (Barclay, 1991), moonlight, air temperature, rainfall rate, wind, relative humidity, metabolic water balance, energetic demands and interspecific competition (Hayes, 1997).

In a study by Fenton and Morris (1976) using 'black light' to attract insects, they found that insectivorous bats were significantly most active during periods when light was on and insects were aggregated over it. The foraging behavior or foraging activity of insectivorous bats consist of four stages that are, search flight (before the detection of prey), approach flight (pursuit after the detection of prey), capture and retrieval of prey (Kalko,

1995) and these stages correlated with phases in the echolocation behavior. In tropical environment, interspecific differences in echolocation within foraging guilds reflect differences of bat abilities to detect prey of different sizes or the structure of foraging habitat (Kingston *et al.*, 1999).

Foraging strategy of insectivorous bats.

Several foraging strategies are evident from work done on insectivorous bats. Some species will response to the prey by greater distances and will only make one attempt to catch a prey item per pass through feeding area while other species only operate at short ranges and make several attempts to capture prey on any pass through feeding ground (Fenton, 1982). Foraging strategy of insectivorous bats may vary according to their flight styles (Gaisler, 1979). Insectivorous bats that glean to take their food from surfaces such as ground, water or foliage usually have large ears and broad wings (Fenton, 1982) while the flycatcher bats do not remain continuously on the wing when foraging (Gaisler, 1979). Different foraging strategies probably will result in different prey being selected.

In a study that by Kingston *et al.* (2003), they had divided the insectivorous bat into three guilds that is defined by degree of clutter such as the vegetation and any other obstacles that bats encounter when foraging. The Strategy I bats will forage in the highly cluttered space within the forest interior while the Strategy II species usually forage in small clearings in the forest, over small streams or at the forest edge. For the strategy III, which applied by the open-space bats, they forage in open spaces above the forest or in large clearings that are clear of clutter. The food habits of insectivorous bats can be influenced by several factors including the time of nightly emergence (Erkert, 1982) and also the size of prey and predator that are positively related (Kunz, 1982). Besides that, there is also a conflict about whether coexisting species of bats feed on different types of food. According to Aldridge and Rautenbach (1987), there are several studies indicated that bats foraging in the same places consume the same food and in some species, spatial and temporal partitioning of food occur (Saunders and Barclay, 1992).

Stephens and Krebs (1986) proposed two models for optimal foraging – the optimal diet model and optimal patch model. Optimal diet is one that includes the set of kinds of prey, which if eaten wherever encountered will maximize the energy intake per unit time. Predicting optimal diet breadth has been the objective of most models of the evolution of food habits. Two basic strategies can be visualized in the case of demographic strategies that are food generalist and food specialist (Churchill, 1994). Insectivorous bats are food specialist that contains relatively low diversity of food items that will be selectively favored under conditions that are during an increase in the absolute abundance or diversity of food, periods of reduced energetic requirements, when foraging occurs via pure pursuit, when selection favors minimizing the amount of time spent foraging and when food is clumped in space (Whitaker *et al*., 1996). Under the optimal patch model, the habitat is assumed to have a patchy distribution of prey within the habitat and may choose habitats, which from previous experience is known to be profitable (Stephens and Krebs, 1986).

3.0 MATERIALS AND METHODS

3.1 Study site.

The research was conducted in Universiti Malaysia Sarawak campus area (GPS 01^{0} 27' 48"N 11^{0} 27' 03"E), located 32 km from Kuching, the capital city of Sarawak. This area was once a peatswamp forest that had been logged and farmed. Recently, large part of the area has been cleared for residential and commercial development. There were six observation sites marked in the map of Unimas (Figure 1), that represent forest edge (A and B), open area (C and D), and close area (D and E). Bat tunnel was set at three sites marked as T1, T2 (open area) and T3 (forest edge).

3.2 Fieldwork

The field work was carried out over 18 nights between October 2005 to February 2006. For each of the six study sites, monitoring of bat and insect activity was done in three consecutive nights starting from 1900 hrs until 2200 hrs. Factors that have been considered for night selection were the non-rainy and dark night in order to avoid the influence of lunar towards insect activity. Observations at the open areas were conducted at the street lights while at the forest edge and close areas, the observation was done at the light source powered by generator.

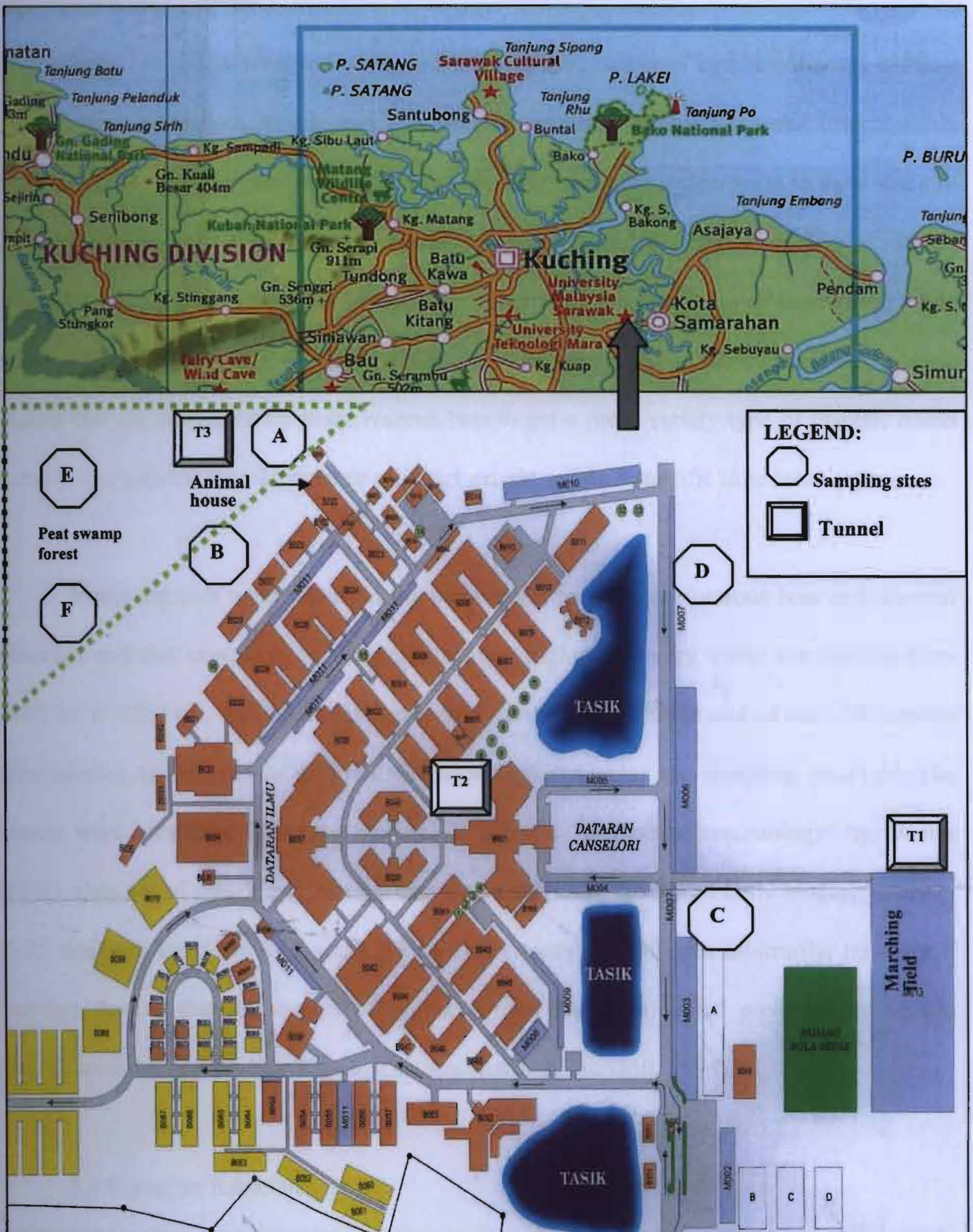


Figure 1: Map of Universiti Malaysia Sarawak showing the locations of study sites (Source: Universiti Malaysia Sarawak, 2005 and Sarawak Tourism Board, 2000).

3.3 Insect activity

In this study, insect activity was indicated by the number of insects collected within a specific time interval. A screen trap was used to sample available nocturnal insects at six study sites. Most of the previous researchers use light trap to sample insects in their study of foraging ecology of specific insectivorous bats species (Churchill, 1994; Hickey *et al.*, 1996). However, in this study there was no specific insectivorous bats species of intention. Due to variety of foraging strategy of insectivorous bats, the screen trap is more efficient to sample insects that are consumed by insectivorous bats to get a more variety type of insects. Insect activity was indicated by the number of insect caught within a specific time interval.

Insect samples were taken on the same night as the insectivorous bats activity was observed and this was done on three consecutive nights for every study site starting from 1900 hrs to 2200 hrs. All the insects on screen were collected at the end of each 30 minutes time interval and placed in different containers according to the sampling intervals. The insects were identified following Saxena (1992) and 'Outline of entomology' by Danies (1988), then sorted into 3 size classes that are small (less than 5 mm body length), medium (5-25 mm) and large (over 25 mm). These size classes were chosen arbitrarily, however it was hypothesize that the insects of within a medium range would preferred by certain insectivorous bat species like *Rhinonycteris aurantius* (Churchill, 1994).

3.4 Foraging behavior

Observations of foraging behavior of insectivorous bats at the open area (site C and D) were made at the street lights while at the forest edge (site A and B) and the close area (site E and F) (Figure 1), a 160 mercury bulb was used as a light source to attract the insects. The street light that have been used for observation was not so high in order to ensure that the bats echolocation calls can be detected. The identification of bat species was made through the frequency of echolocation calls produced by Mini-3 bat detector (Ultra Sound Advice, London, United Kingdom) and the bat frequencies recorded were then referred to data of previous studies (Hall, 1996; Hall *et al.*, 2002). Specifically, the surrounding area was scanned slowly but continuously sweeping up and down through a frequency range from 15 to 160 kHz. The detector was manually triggered whenever a bat call was audible through the speaker or a bat was directly observed flying past the light source. The bats activity was counted as the number of passes the bat made during a specified sampling interval

In order to increase the accuracy of bats identification, a tunnel was made using two mist nets (10 x 2.5m and 30mm mesh size) and a four bank harp trap and the tunnel was placed at two sites of open area (T1 and T2) and one site at the forest edge (T3). The tunnel was set up to perform a 'V' shape with the harp trap at the end of the tunnel. The four bank harp trap was used to increase the efficiency of catching Microchiropterans (Wilson *et al.*, 1996). A light source was set up at the end of the tunnel to attract the bat and the tunnel was checked every 30 minutes.

The correlation of activity of insectivorous bat and insect and also the correlation of size of insectivorous bats and insects were analyzed using SPSS 11.5 for Windows (SPSS Inc, 2002), and simple linear correlation was employed to assess these relationships.

4.0 RESULTS

4.1 Insect activity

A total of 2,325 individuals of insects were collected using the light sheet throughout the 18 nights of sampling. The majority of insects collected belong to the order Coleoptera, Hymenoptera, Hemiptera, Lepidoptera, Diptera, and Orthoptera. The total number of insects collected at close area was highest, followed by forest edge and the lowest was at the open area (Figure 2). Out of the total number of insects collected, 52% were of medium size while small and large size insects account for 36% and 12% of the total respectively. The lowest insects activity rates were recorded at the forest edge areas and this might be due to the existence of more light at the open area nearby that were more attractive to the insects.

There were not much difference in insect size composition between open area and forest edge as both places have more insect of medium size class. In contrast, at the close area the activity of small size insects was double of that of the open area and forest edge (Figure 2). The large class insects were seen to be less active than small and medium size insects throughout the sampling period.

It was hard to determine the active hour of insects as the total activity pattern was almost the same throughout the six time interval (Figure 3). The activities of insects were observed as not to be influenced by the type of light source used as the totals were almost the same both at the yellow light street and the white light source.

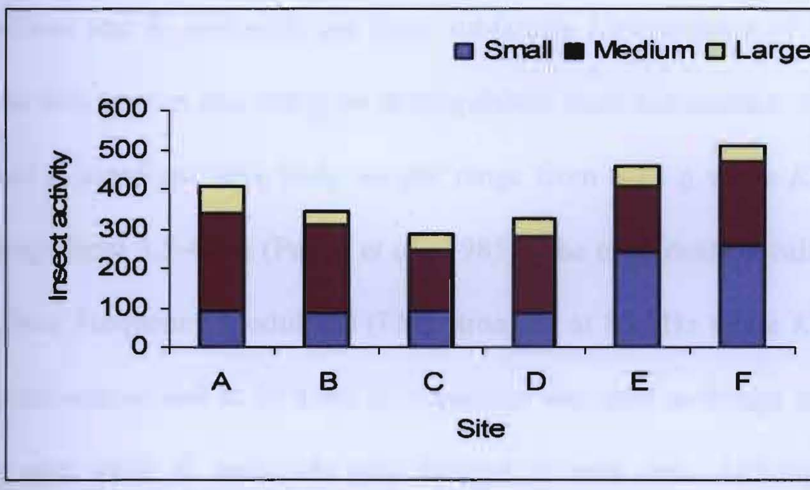


Figure 2: Insects activity (no. of insects) at six study sites (site A and B – forest edge, site C and D – open area, site E and F – close area).

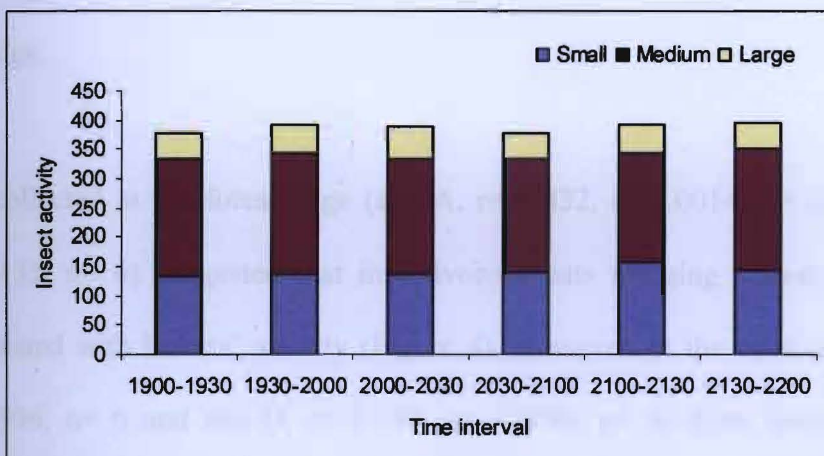
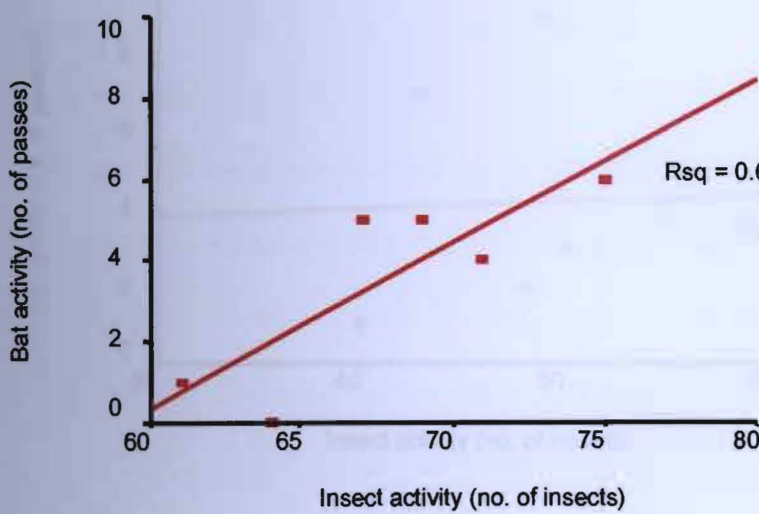


Figure 3: Total insects activity (no. of insects) due to time interval of 18 sampling nights.

4.2 Foraging behavior

During the total of 18 nights of observation, only two species of insectivorous bats could be identified through bat detector as they were passing by the light sources and these were *Kerivoula papillosa* and *Kerivoula pellucida*, while the other three individuals could not be identified due to their fast flight. The bats that passed by were assumed to forage at the light source. However, no bats were captured using the tunnel made.

Site A



Site B

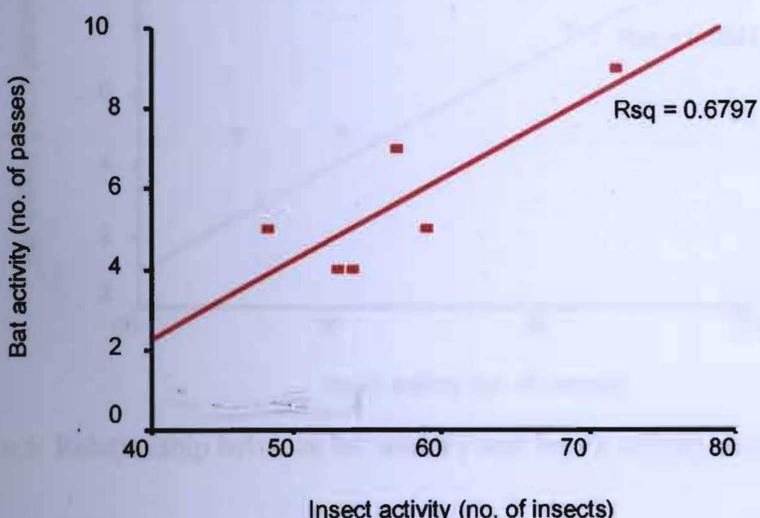
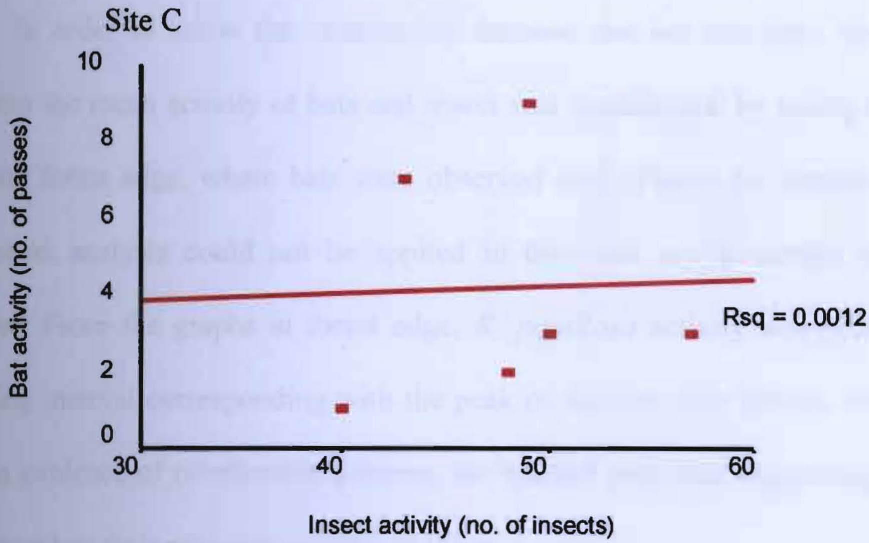


Figure 4: Relationship between bat activity and insect activity at forest edge (Site A and B).



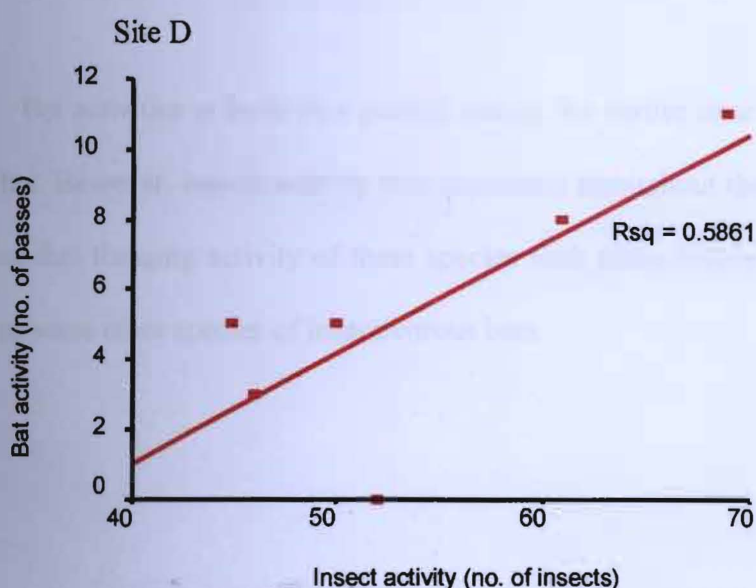


Figure 5: Relationship between bat activity and insect activity at open area (site C and D).

In order to know the relationship between the bat and prey size, bar graphs that represent the mean activity of bats and insect was constructed, by taking the data from open area and forest edge, where bats were observed only (Figure 6). However, a simple linear correlation analysis could not be applied in this case as for certain nights, no bat was detected. From the graphs at forest edge, *K. papillosa* activity was peaked during second sampling interval corresponding with the peak of medium size insects. Nevertheless, there was no evidence of relationship between the bat and prey size suggesting that these species actively select their prey with respect to the size.

Bat activities at both sites peaked during the earlier time interval but decreased after 2100 hrs. However, insects activity was consistent throughout the three hours sampling. This resulted that foraging activity of these species took place within these hours and not late at night as some other species of insectivorous bats.